Non-IP Networking (NIN)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY **4**

1 INTRODUCTION **4**

2 HISTORICAL BACKGROUND: DATAGRAMS VS. VIRTUAL CIRCUITS **6**

3 ANALYSIS OF THE TERMS OF REFERENCE OF NIN ISG **8**

3.1 NIN Terms of Reference **8**
3.2 Key Performance Indicators **9**
3.2.1 Naming and Addressing KPIs 9
3.2.2 Performance KPIs 10
3.2.3 Mobility KPIs 10
3.2.4 Buffering KPIs 10
3.2.5 Multihoming KPIs 10
3.2.6 Protocol Efficiency KPIs 11
3.2.7 Security and Privacy KPIs 11
3.2.8 Traffic Management KPIs 12
3.2.9 Interoperability KPIs 12
3.2.10 Perspective on NIN-IGP KPIs 12
3.3 Flexilink **12**
3.3.1 Flexilink roots, publications and patents 13
3.3.2 Basic service 13
3.3.3 Guaranteed service 13
3.3.4 Synchronous vs asynchronous service 14
3.3.5 Implementation in wireless devices in radio networks 14

4 2021 NIN GROUP REPORTS **15**

4.1 NIN001: Problem statement: networking with TCP/IP in the 2020s” **15**
4.2 NIN002: “Implementing Non-IP networking over 3GPP cellular access” **16**
4.3 NIN003: “Flexilink Network Model” **17**

5 NIN VS NEW IP **17**

6 ANALYSIS **18**

6.1 Back to the Future: Replacing IP Headers with Virtual Circuits **18**
6.1.1 Header compression 18
6.1.2 Control Plane Overhead 19
6.1.3 Flow State Overhead 19
6.1.4 Routing Around Failures 20
6.1.5 Complexity 20
6.1.6 Quality of Service (QoS) 21
6.2 Flexilink for wireless device to gateway communication **21**
6.3 Application identifiers **22**

7 CONCLUSION 23

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This document supports ICANN's strategic goal to improve assessment of, and responsiveness to, new technologies which impact the security, stability, and resiliency of the Internet's unique identifier systems by greater engagement with relevant parties. It is part of ICANN's strategic objective to evolve the unique identifier systems in coordination and collaboration with relevant parties to continue to serve the needs of the global Internet user base.

Executive Summary

In April 2020, European Telecommunications Standards Institute (ETSI) started a new Industry Specification Group (ISG) on “Non-IP Networking,” or NIN. ISGs are not part of the standard making committees of ETSI; they are designed to be quick and easy to set-up. The NIN ISG published its first group reports in March 2021.

Similarly to the Huawei New IP proposal, the starting point of ETSI NIN ISG is the claim that TCP/IP is an old protocol, unsuitable for the new types of applications promised by 5G, such as tactile applications and industrial robots. However, NIN takes a different approach than New IP. Instead of extending the IP header to include more information, such as a Quality of Service (QoS) contract to be enforced by routers and switches, NIN proposes a virtual circuit approach, where packets are classified into flows in a Software Defined Networking (SDN) model that are then forwarded by switches according to virtual circuit identifiers associated with the flows. The technology promoted by NIN is called Flexilink and was documented by a prior ETSI ISG: “Next Generation Protocol (NGP).” Flexilink is, in many aspects, reminiscent of Asynchronous Transfer Mode (ATM), a networking approach that briefly became popular in the 1990s but which by 2005 had largely faded from the telecommunications world, or Multiprotocol Label Switching (MPLS), a technology largely deployed today by Internet Service Providers (ISPs).

It remains unclear if NIN could be a full-blown replacement of IP or something to be used only in specific local applications, for example, at home or in industrial networks that are outside the scope of the Internet. At this stage, NIN very much remains a research exercise, not an engineering one. Some experimental code might exist, but the ISG has not yet come up with a complete and interoperable proposal. In particular, the NIN model relies heavily on an as yet undefined external protocol to signal the creation, modification or deletion of virtual circuits. It is unclear at this point which signaling protocol will be chosen or how it would work. It is worth noting that any simplification that NIN could bring should be balanced with the extra complexity and cost that the unspecified signaling protocol for virtual circuit creation, modification or deletion might add.

1 Introduction

The European Telecommunications Standards Institute (ETSI) has been working on networking evolution for a number of years. Relatively recently, it created an Industry Specification Group (ISG) on Network Function Virtualization (NFV) in 2012 and an ISG on Next Generation Protocols (NGP) in 2015.[1]

In April 2020, ETSI created a new ISG on Non-IP Networking (NIN) to develop the work of the NFV and NGP ISGs further. John Grant, BSI,[2] is the ISG Chair, and Kevin Smith, Vodafone,[3] is the ISG Vice Chair. The complete list of participants to the ISG is not public. The first three Group Report (GR) documents were published in March 2021.

[1] See https://www.etsi.org

[2] See https://www.securityinformed.com/companies/building-solution-international-bsi.html

[3] See https://www.vodafone.com/about

According to ETSI, ISGs are “Industry Specification Groups that operate alongside our traditional standards-making committees in a specific technology area. They are designed to be quick and easy to set up. They provide an effective alternative to the creation of industry fora.[4]

The initial assumption of this effort is that the TCP/IP protocol suite, now 40 years old, is no longer suitable for modern networking. In a nutshell, NIN is proposing to go back to a model of virtual circuits, in which network traffic is grouped into flows. Contrary to IP datagrams in which each packet contains a header including the source and destination of the traffic so intermediary routers can take independent decisions on how to forward the packet, virtual circuits are set-up once before the traffic flows, and each packet only needs a simplified header that contains a flow number.

Circuit-switching, and then virtual circuits, were the foundation of the telephony model. A conduit is established (a circuit is set-up) at the beginning of the communication and torn down at the end of the communication. Each packet related to the same communication flow is simply put inside the virtual circuit. This telephony networking model has been replaced on the Internet by the datagram model. In this latter model, there is no communication establishment needed prior to sending data: each packet contains enough information put in a specific header to enable routers to make independent decisions on how the packet should be forwarded. This feature allows for a quick dynamic reconfiguration of the network in case of outages.

NIN claims that the IP header makes up a non-negligible portion of an IP packet and creates unnecessary overhead, especially for “Internet of Things” (IoT) devices. The Internet Engineering Task Force (IETF) has standardized a method to compress, and sometimes entirely eliminate, IP headers: RObust Header Compression (ROHC). However, NIN proponents argue that ROHC requires a specific license to be activated on routers and that cellular ISPs are unwilling to license that technology except for very specific services. It remains unclear that developing and deploying new technologies would be more cost effective than paying those licensing fees or if the exercise would not simply end-up in shifting those costs to other parties.

NIN is not the only effort revisiting the foundations of IP. For example, the “New IP” proposal from Huawei makes similar claims about the non-suitability of TCP/IP. New IP also has roots in ETSI NGP,[5] but instead of proposing to remove the IP header altogether, it proposes to extend it. As such, New IP is sometimes referred to as “Big IP.”

This paper will first provide some historical background on a key technology underlying the Internet, then take a look at the publicly available documentation of the technology which NIN proposes to develop. Next, it will briefly compare NIN to New IP before analyzing the impact that NIN could have on security, stability and resiliency of the system of unique identifiers which ICANN helps to coordinate. This study was started under the ICANN 2021-2025 Strategic Plan, Objective 3 that requires ICANN to “embrace the rapid evolution of emerging technologies, business, and security models” in order to maintain its agility as the Internet evolves.[6] Not all technology proposals are equal. Some may provide benefits for certain users but put the security, stability, or resiliency of the system of unique identifiers that ICANN helps coordinate at

[4] See https://www.etsi.org/about/our-operations

[5] See https://www.lightreading.com/5g/non-ip-squares-up-to-new-ip-in-battle-for-internets-future/d/d-id/758771

[6] “ICANN Strategic Plan for Fiscal Years 2021- 2025," June 2019, https://www.icann.org/en/system/files/files/strategic-plan-2021-2025-24jun19-en.pdf

risk. As such, understanding the impact of emerging technologies is required to assess whether they should be embraced.

2 Historical background: Datagrams vs. Virtual Circuits

NIN is questioning a fundamental aspect of the Internet, the datagram model, and is promoting virtual circuit or virtual-circuit-like technologies as a novel way to address perceived problems. It is worth remembering that there is a history going back decades about the tussle between these two different networking models.

Early telephony networks were based on the notion that a physical electric circuit had to be established between the two ends of a communication to allow for a flow of voice signals. In the early days, human operators had to manually connect lines together on switching boards to achieve these physical circuits. The Strowger switch (circa 1891) was the first commercially successful automatic circuit switch. The story[7] goes that Strowger, an undertaker, was seeing his business failing. Trying to understand what was happening after one of his friends passed away but he did not get the business, Strowger believed the problem originated from a woman, operating as a local telephone switch operator. She was allegedly romantically involved with his competitor and, according to Strowger, was re-directing people calling for his service to her lover. This motivated Strowger to create a device that would automate the switching task and protect him from what we would call today a man in the middle attack.

Early digital or data networks have extended this circuit model with the notion of virtual circuits that are configured by software. Once virtual circuits are established, user applications no longer need to care about the network; they just need to send data. Intermediary switches forwarding data only need to connect the incoming "pipe" with the outgoing "pipe" according to local configuration or to instructions received through a connection establishment protocol. Managing the capacity of the links and the switches is typically a major concern in telephony networks, and a great deal of effort has been devoted to allow for the reservation of capacity. The resulting signaling protocols are where the complexity of such networks lies. Signaling System 7 (SS7) was one of the latest signaling protocol suites developed by the ITU-T to establish telephony communications. It was standardized in the mid 1970s in recommendation Q.700.[8]

One of the issues of circuit-based networks is resiliency: when a line or a switch fails, connections break down and have to be re-established. In 1962, Paul Baran proposed developing a network where small messages would be stored and forwarded by computer nodes in a redundant computer network.[9] Those messages would include the source and destination addresses of the communication end-points, so they could be independently processed by any intermediary computer. If a link or a node were to fail, the previous node would have enough information to re-route the message.

[7] See http://www.strowger.net/conspiricy-behind-strowger-as-an-inventor/
[8] See https://www.itu.int/rec/T-REC-Q.700/en
[9] See http://pages.cs.wisc.edu/~akella/CS740/F08/740-Papers/Bar64.pdf

The terms “packet[10]” and “packet switching” were introduced in the networking context 1967 in a seminal paper from Donald Davies.[11]

The ARPAnet was described in a paper from Lawrence Roberts in 1970.[12] The ARPAnet was a hybrid system. The core network was using packet switching, but the periphery (the Interface Message Processors or IMPs[13]) dealt with packet loss and packet reordering before presenting the traffic to the user’s application.

In 1973, Louis Pouzin designed Cyclades, the first network implemented using solely Baran’s and Davies’ networking model. Pouzin and his team (Hubert Zimmerman and Gérard LeLann) also implemented an end-to-end transport protocol that would offer applications the equivalent of a virtual circuit. Cyclades’ ideas became major contributions to the development of (what would become) the Internet’s core protocols, the Transmission Control Protocol (TCP) and the Internet Protocol (IP). These Cyclades’ protocols are mentioned in the reference section of RFC675: “Specification of Internet TCP.[14]

In January 1974, a meeting of the Consultative Committee on International Telephone and Telegraph (CCITT), predecessor[15] of the ITU-T, established a list of study points to be considered to answer the question “what is packet switching?” This list included two main versions of packet switched services, a “datagram service” and a “virtual call service.”[16] The term “datagram” was actually coined by Halvor Bothner-By, the Norwegian rapporteur of that CCITT study group, by combining the word “data” with the word “telegram.”[17] Prior to that, datagrams were simply called “independent packets,”18 referring to the fact that intermediary computers could independently process them.

The subsequent years saw major and often heated discussions about the relative merits of virtual circuit and datagram-based network architectures. These discussions peaked in the mid-1990s with the advent of Asynchronous Transfer Mode (ATM).[19] In the technical world, the participants in the discussions on ATM were frequently pitched as the “Bell heads” (telephony system architects) vs. the “Net heads” (data network architects).[20] Ultimately, the commercial failure of ATM and the success of TCP/IP in the late 1990s and early 2000s basically settled the issue, at least from a market perspective. However, the virtual circuits architecture never went away and the discussions on its merits and drawbacks, particularly in relation to new demands

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[10] The term “packet” was used much earlier, as in “packet boats” used to carry freight and mail along rivers and canals in the 18th century. See https://en.wikipedia.org/wiki/Packet_boat

[11] See https://people.mpi-sws.org/~gummadi/teaching/sp07/sys_seminar/how_did_erope_blow_this_vision.pdf

[12] See https://www.researchgate.net/publication/234815171_Computer_Network_Development_to_Achieve_Resource_Sharing

[13] See https://tools.ietf.org/html/rfc7

[14] See https://tools.ietf.org/html/rfc675 section 7

[15] See https://www.itu.int/en/history/Pages/50YearsITU-T.aspx

[16] See https://doi.org/10.1145/1024916.1024918

[17] See http://old.open-root.eu/la-doc/histoire-des-reseaux/le-datagramme/

[18] See https://conservancy.umn.edu/bitstream/handle/11299/155671/oh421rd.pdf?sequence=3&isAllowed=y page 11

[19] See https://web.archive.org/web/20050701081559/http://www.atmforum.com/

[20] See https://www.wired.com/1996/10/atm-3/

on networks,[21] resurfaces from time to time. Historically, virtual circuit proponents usually explain that the IP datagram architecture and the TCP end-to-end congestion control are unsuitable for the next generation of applications, like voice, video, and any other communication form that is seen as needing QoS guarantees. However, the experience over the last 20 years has shown that the TCP/IP protocol suite has been able to evolve to accommodate new types of applications. To date, regular increases in available bandwidth and the corresponding decrease of the price thereof has essentially solved whatever quality of service problem there might have been.

3 Analysis of the Terms of Reference of NIN ISG

The NIN ISG terms of reference are published on the ETSI portal.[22] "Work in progress" documents of the NIN ISG are only available to ETSI members and NIN ISG participants. In order to become a participant, organizations need to sign the ISG Participant Agreement.[23] This prohibits a wider review of those "work in progress" documents by external experts. As a result, this paper is based exclusively on public sources.

3.1 NIN Terms of Reference

The NIN ISG terms of reference stipulates that the ISG intends to work on:

- "documenting the requirements for the network protocols that can natively and efficiently support the evolving demands of infoComms[24] towards 2030 and beyond;"
- "documenting the eventual shortcomings that currently exist or are likely to emerge in current network protocols; and"
- "formulating a series of Group Specifications defining new protocols that can meet the requirements for future networks."

The area of work defined in the terms of reference include, but is not limited to:

- "extension of the technology specified in GS NGP 013[25] to the RAN[26]"
- "control plane protocols and network management"
- "addressing and identification"
- "timing and synchronisation"
- "security and privacy"
- "interworking with legacy systems"
- "Test results and proof points:"

[21] Those demands are often related to local networks, or to specific access technologies, not to the Internet at large.
[22] See https://portal.etsi.org/Portals/0/TBpages/NIN/Docs/ISG_NIN_ToR_D-G_APPROVED_20200211.pdf
[23] See https://etsisign.eu1.echosign.com/public/esignWidget?wid=CBFCIBAA3AAABLblqZhDVoAhh0L-i4ZmBhhkVioh6uWY6RQ4cyX3WIp1gagHVwsoM3xVKuZssISM343pxgOA*
[24] This is an ETSI term of art
[25] See https://www.etsi.org/deliver/etsi_gs/NGP/001_099/013/01.01.01_60/gs_NGP013v010101p.pdf
[26] This is an ETSI term of art

- "benchmark against the KPIs published in GS NGP 012,[27] in order to demonstrate benefit in comparison to current network protocols"
- "interworking and coexistence between NIN and IP-based domains"
- "implementation guidelines and considerations, including interoperability test cases"
- "interoperability Plugtests"
- "publication of test results"

As mentioned above, ETSI NIN ISG work in progress documents are not publicly available. As such, this paper will limit its analysis on the two elements mentioned in the terms of reference and described in publicly available documents:

- The Key Performance Indicators (KPI) chosen in ETSI GS NGP 012
- The Flexilink architecture proposed in ETSI GS NGP 013

As will be shown in the analysis in Section 6, Flexilink is essentially the combination of a virtual circuit architecture augmented by a Software Defined Network (SDN) approach.

3.2 Key Performance Indicators

ETSI GS NGP 012 offers Key Performance Indicators (KPIs) in the following areas:

- Naming and addressing
- Performance
- Mobility
- Buffering
- Multihoming
- Protocol efficiency
- Security and privacy
- Traffic management
- Interoperability

The objective of the ETSI NIN ISG is to evaluate those KPIs for the TCP/IP protocol suite and apply the same KPIs to any proposal coming from the NIN ISG. It should be noted that defining those KPIs and their desired values may not have been a neutral exercise. They may be, by the very nature of the exercise, influenced by the goals of the party selecting them.

3.2.1 Naming and Addressing KPIs

These KPIs are targeted at the addressing system. They include:

- Number of entities addressable
- Address management
- Separation of locator and identifier
- Independent application names

Application names are identifiers independent from the address of the host the applications reside on. In contrast, regular DNS names typically resolve to IP addresses, which bind the application to a particular host.[28]

[27] See https://www.etsi.org/deliver/etsi_gs/NGP/001_099/012/01.01.01_60/gs_NGP012v010101p.pdf

[28] The DNS can be extended with new resource record types for specific usage. The SRV resource record type is one that comes to mind that could serve this purpose.

3.2.2 Performance KPIs

The KPIs target network performance in terms of:

- Latency
- Jitter
- Packet loss
- Delivery in order

The circuit switched networking model guarantees in-order data delivery and, via resource reservation during circuit set up, constrained latency, jitter, and packet loss. IP implements a network datagram model in which the constraints of in-order delivery of data and packet loss have been relaxed, leaving it to end-points to reorder or retransmit packets. Thus, this KPI is not neutral. Any datagram oriented technology would naturally score much less here than a circuit switched technology.

3.2.3 Mobility KPIs

The mobility KPIs include:

- Latency of handover
- Memory overhead of handover
- Packet loss of handover

3.2.4 Buffering KPIs

The buffering KPIs include:

- Ability for applications to specify how intermediary routes should treat congestion, either by queuing or by dropping packets
- Support for various queuing mechanisms

In the datagram model, there is a strong decoupling of end-points from the core network. TCP/IP does not allow for applications to specify how queueing should happen.[29] A virtual circuit oriented architecture in which the core and the end-points are tightly coupled might decide to allow end points to specify a queuing mechanism.

3.2.5 Multihoming KPIs

The multihoming KPIs include:

- Do the protocols name the node and not the network interface?
- Do the protocols support aggregation of content from different destination sources to provide resilience?

[29] RFC 2474 (see https://tools.ietf.org/html/rfc2474) defines “Differentiated Services” code points. Some special IP or TCP options could be defined to also indicate how queuing should be done, but there will not be any guarantee such requests would be honored by intermediary routers.

The IP architecture is described in RFC 791.[30] In Section 2.3 "addressing," it clearly states that IP addresses are attached to interfaces, not hosts. This presents a well known issue for multihoming and mobility: when a host changes a network attachment, its IP address changes and sessions need to be restarted. This question was revisited in the late 1990s during the IPv6 standardization, but, in the end, the model remained the same. In a virtual circuits model, addresses are attached to hosts. The actual routing of the packets to the correct interface is left to the signaling protocols. When a host changes an attachment, the signaling protocol will have to re-configure the network path. In other words, changing the model of what an IP address is representing (an interface of a node) does not entirely solve the multi-homing complexity; it moves the location of where this complexity is handled.

3.2.6 Protocol Efficiency KPIs

The protocol efficiency KPIs include:

- The ratio of useful data in the payload to the overhead such as header size
- Number of instructions required to process headers
- Memory required to process headers
- Impact of multihoming, traffic engineering on routing table size
- Number of round trips required to establish a connection
- Retransmission of data already queued somewhere
- Number of network hops to report and react to congestion
- Security overhead (CPU and memory)
- Should endpoint addresses be encapsulated in every packet?

One of the key differences between datagram and circuit switching is that, from a host perspective, a virtual circuit is essentially a straight pipe to the destination. An application can read data from it or write data directly into it. A connection, or network path, is created out of band at the beginning of each communication. Intermediary nodes must keep the state of each flow to know the location of the next hop. In a datagram model, intermediary nodes do not keep the state of the flows. They route packets based on the destination address which is included in each packet. The task of establishing the connections is left to a higher-layer protocol (e.g., TCP) at the end-points. Any application using TCP would also experience a "straight pipe."

3.2.7 Security and Privacy KPIs

The security and privacy KPIs include:

- Is security on by default?
- Does it follow the ETSI security framework?[31]

It should be noted that what "security" means is not specified in ETSI GS NGP 012.

[30] See https://tools.ietf.org/html/rfc791

[31] An overview of ETSI work on security in Information and Communications Technologies (ICT) can be found at https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp1_security.pdf. ETSI Cyber "Design requirement ecosystem" document can be found at https://www.etsi.org/deliver/etsi_tr/103300_103399/103369/01.01.01_60/tr_103369v010101p.pdf

3.2.8 Traffic Management KPIs

The traffic management KPIs include:

- Latency in identifying traffic for QoS
- Volume of data to be analyzed for QoS
- Capabilities of traffic management policies

Similarly to Section 3.6, in a datagram networking model, QoS is managed by intermediary nodes, on a per-packet basis. In a circuit-switching model, these parameters are set once at the creation of the virtual circuit.

3.2.9 Interoperability KPIs

The interoperability KPIs include:

- Compatibility with TCP/IP
- Compatibility with 3GPP R15/16[32]

Note: This KPI obviously cannot be applied to TCP/IP itself. 3GPP R15[33]/16[34] are the standardization documents developed by 3GPP for 5G.

3.2.10 Perspective on NIN-IGP KPIs

As will be discussed below, most of the KPIs defined in ETSI GS NGP 012 are not neutral. They can better be described as a list of criteria to differentiate between a datagram networking model and a circuit-switched one or a set of requirements to be used in defining a new, virtual circuit-based network architecture. Applying those KPIs to TCP/IP would naturally lead to a poor score. Conversely, applying them to any virtual circuit networking model, such as ATM or the Flexilink proposal that the ETSI NIN ISG is proposing to extend, would inevitably bring a much higher score.

Also, the scope of those KPIs is not well defined. Measuring performance in a controlled network is very different from doing the same in an inter-domain environment, in which multiple business models can compete.

3.3 Flexilink

Flexilink is a protocol described in ETSI GS NGP 013. The NIN-IGP terms of references propose to extend or adapt it to the radio access network (RAN) in a 5G world. However, as a solution it is incomplete. In particular, the control plane to create, modify, or delete virtual circuits will need to be defined.

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[32] 3GPP R15 and R16 are the latest specifications published by 3GPP. See https://www.3gpp.org/specifications/67-releases Those specifications are the technical basis of what is commonly referred to as “5G.”

[33] See https://www.3gpp.org/release-15

[34] See https://www.3gpp.org/release-16

The work-in-progress documents from the NIN-IGP are not available to the public, so this section will limit its focus on Flexilink as described in ETSI GS NGP 013.

According to ETSI GS NGP 013, Flexilink "specifies user plane packet formats and routing mechanisms for 5G core and access networks based on the requirements of ETSI GS NGP 012." It should be observed that the last part of the above quote appears to confirm the perspective that will be noted in Section 3.10 of this document: that ETSI GS NGP 012 is not a set of KPIs but a requirement document for a new networking protocol.

Flexilink, as a user plane, can function in two modes: basic service for legacy support and guaranteed service for new applications requiring a specific QoS.

The fundamental concept behind Flexilink is the classification of packets into flows. A flow is a sequence of packets with a beginning and an end. At the creation of each flow, a new path is instantiated in the network elements in a way reminiscent of virtual circuits. This is done by a control plane protocol that is not specified in ETSI GS NGP 013.

3.3.1 Flexilink roots, publications and patents

The work on Flexilink largely pre-dates its definition in ETSI GS NGP 013 published in 2018. We can find an early description of Flexilink by John Grant, the chair of the NIN ISG, dating back to 2012 in a paper published in the 133rd AES Convention.[35] This paper references a 2010 U.K. patent[36] application by John Grant on the same topic linked to an early 2009 filing.[37]

3.3.2 Basic service

Basic service is defined in Section 5 of ETSI GS NGP 013. This service is meant for intermittent communications that do not require a capacity reservation. In the basic service each flow is associated with a unique label. When transmitting data, that label is followed directly by the payload and some control messages.

Basic service flows have a single destination, but can support multiple sources. This basic service appears to be similar to Multi-Protocol Label Switching (MPLS)[38] encapsulation and, thus, can also be understood as a layer 2.5 protocol in the ISO-OSI model.[39]

3.3.3 Guaranteed service

According to ETSI GS NGP 013, the guaranteed service is intended for "digital audio and video, tactile feedback, and position of vehicles and industrial robots." In contrast to the basic service,

[35] See "Flexilink: A unified low latency network architecture for multichannel live audio"; Wang, Grant, Foss; 133rd AES Convention, San Francisco USA, October 2012. Available at https://dmtlab.bcu.ac.uk/leowang/mypapers/201210%20Flexilink%20A%20unified%20low%20latency%20network%20architecture%20for%20multichannel%20live%20audio.pdf

[36] See https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2010082042

[37] See https://patentscope.wipo.int/search/en/detail.jsf?docId=GB135176547&_fid=WO2010082042

[38] See https://tools.ietf.org/html/rfc3031

[39] See https://www.iso.org/ics/35.100/x/

each guaranteed service flow can have exactly one source but multiple destinations, making it more suitable for multicast applications.

ETSI GS NGP 013 specifies that “Each flow shall support a defined number of packets per second, negotiated by the control plane protocols when it is set up, and should have resources allocated such that latency is bounded and packets will not be lost due to congestion.”

In other words, the guaranteed service of Flexilink establishes a full virtual circuit via an unspecified control plane that will set up QoS parameters such as the exact bandwidth and maximum latency. Because it is a virtual circuit, it will not lose packets.

This is an architectural trade-off of the virtual circuit networking model. As explained earlier, the data plane is simplified at the expense of the control plane. Flexilink does not specify which control planes it will use nor how it would work.

3.3.4 Synchronous vs asynchronous service

Flexilink guaranteed services can be either synchronous or asynchronous.

Synchronous service – Synchronous mode capable Flexilink flows are formatted in time slots that can transmit up to 64 octets. Each guaranteed flow will be allocated a number of slots per its allocation period. Empty packets will be transmitted to fill-up extra capacity. This formatting in slots is reminiscent of the 53-byte ATM cells or local area networks (LAN) such as Fiber Distributed Data Interface (FDDI)40 and Token Ring.41

For this synchronous mode to work, each intermediary network element must keep a clock that is synchronized with the others. This synchronization of clocks is left to the unspecified control plane.

Asynchronous service – In the case that synchronization is not an option, the guaranteed service is delivered over the basic service. QoS is then negotiated on each intermediary link by the unspecified control plane.

3.3.5 Implementation in wireless devices in radio networks

ETSI GS NGP 013 suggests that the basic service could be implemented on radio links.

It is the author's understanding that this could be done using a shim library running on the wireless devices. Most applications use some variation of the Berkeley Software Distribution (BSD) socket application programming interface (API).[42] A shim library could intercept the connect() call to go and set up a flow with a gateway. The shim library would then also remap the function, send(), to send the payload data directly to that gateway using the Flexilink basic

[40] See https://networkencyclopedia.com/fiber-distributed-data-interface-fddi/
[41] See https://networkencyclopedia.com/token-ring/
[42] See “Unix Network Programming, Volume 1 : The Sockets Networking API,” W. Stevens, Addison-Wesley Professional Computing

service. The gateway would receive this data and reconstruct IP packets on behalf of the device to be sent further into the network. On the return path, the wireless device's shim library could remap the receive() call to read data from the Flexilink. A similar mechanism has been suggested in the IPv4 to IPv6 transition. It is known as "Bump in the API," RFC3338.[43]

4 2021 NIN Group Reports

NIN ISG published 3 Group Reports in March 2021:

- NIN001: "Problem statement: networking with TCP/IP in the 2020s"[44]
- NIN002: "Implementing Non-IP networking over 3GPP cellular access"[45]
- NIN003: "Flexilink network model"[46]

Group Reports are the first level in the ETSI hierarchy of documents. They are "a deliverable, containing only informative elements, approved for publication by an Industry Specification Group."[47]

The NIN ISG is still active.

4.1 NIN001: Problem statement: networking with TCP/IP in the 2020s"

NIN001 starts by observing that the radio spectrum is a regulated, finite, and expensive resource. Maximizing the efficiency of the use of the spectrum is thus a key goal for cellular network operators.

NIN001 goes through a set of techniques that can be deployed at the radio layer and then looks at the networking layer. Data transmission is not a contiguous flow of bits, but a series of packets that are sent over the network. Each packet contains two elements: a header allowing the network to forward the packet, and a payload, that is a portion of the actual data to be transmitted. From an application perspective, packet headers can be viewed as a form of "network tax," an overhead necessary for the good operation of the network. Maximizing efficiency at the network layer means minimizing this overhead.

The typical size of an IP header is 20 bytes in IPv4 and 40 bytes in IPv6. The typical maximum packet size is 1,500 bytes, a value derived from the typical transmission unit on Ethernet networks. For large data transfers that fill up a significant number of maximum sized packets, the overhead is negligible. However, voice packets and status messages sent by IoT devices tend to be much smaller, sometimes just a few bytes per packet, and thus, this IP header overhead can be a serious burden. NIN001 notes that the IETF has developed "RObust Header Compression" (ROHC) to solve this problem, reducing the header size to essentially zero. However, NIN001 states that cellular operators are unwilling to deploy it mainly because of

[43] See https://datatracker.ietf.org/doc/html/rfc3338
[44] See https://www.etsi.org/deliver/etsi_gr/NIN/001_099/001/01.01.01_60/gr_NIN001v010101p.pdf
[45] See https://www.etsi.org/deliver/etsi_gr/NIN/001_099/002/01.01.01_60/gr_NIN002v010101p.pdf
[46] See https://www.etsi.org/deliver/etsi_gr/NIN/001_099/003/01.01.01_60/gr_NIN003v010101p.pdf
[47] See https://www.etsi.org/standards/types-of-standards

licensing costs. The computational and energy costs of ROHC for both the end device and the operator’s equipment is mentioned are neither detailed nor quantified.

NIN001 observes that, at the transport layer (TCP), congestion control is performed end-to-end. NIN001’s perspective is that this is not efficient in radio networks where radio links and transmission of packets is tightly managed by radio schedulers. NIN001 suggests that a shorter control loop (essentially leaving bandwidth micro-management to each radio scheduler) would be more efficient.

NIN001 goes over the history of IP address allocation, noting the imbalance of IPv4 allocations between regions. NIN001 says in Section 5.2:

“The current address allocation model for IPv4 and IPv6 addresses is a centralized-model; it is characterized by:

- Monopoly: where few entities govern the allocation of addresses, (i.e. IANA and the 5 Regional Internet Registries (RIRs) for IPv4 and IPv6 addresses allocation).
- Unfairness: In the 90's, Class-B IPv4 subnets (/16) were assigned to many hospitals and small businesses in the USA.
- Justification: Requesting entities need to justify their needs of addresses. Also, the requesting entities can only be Internet service providers or telco providers.
- Renewal/maintenance: Addresses' owners need to pay annual recurring fees for renewal of their allocated addresses (cost varies per RIR per subnet IPv4/IPv6).”

NIN001 explains that in the IP model, addresses are assigned to interfaces, not nodes. This makes device configuration and discovery easier, but the trade-off is when a device changes the network attachment points, its addresses change and that complex mobility solutions must be deployed if one wants to achieve IP level mobility, ensuring the move is transparent to higher level applications.

NIN001 then observes that “The Internet was designed to carry messages between computers,” not real-time data. IP is a connectionless service (datagram oriented) in which “each packet is self contained.” NIN001 claims that the lack of resource reservation to guarantee bandwidth or latency “results in the poor service that is experienced by users of videoconferencing and voice-over-IP applications.” These assertions are not backed up by empirical data within NIN001.

4.2 NIN002: “Implementing Non-IP networking over 3GPP cellular access”

NIN002 mentions that a non-IP layer 3 solution could be tested on a 5G network using VPN type solutions, but that would be suboptimal as it would increase the header overhead. Thus, a native solution to carry an alternate layer 3 solution is needed, essentially treating the 5G network as a layer 2 service.

NIN002 goes over a variety of approaches, noting that Network Slicing, a widely touted feature of 5G, is not a viable solution due to the higher overhead incurred.

A third approach, called “clean slate,” is to simply use the 5G network as a physical radio layer. This approach, it is argued, would provide the most benefits at the cost of a requirement to completely re-architect the entire 5G ecosystem in order to “encode digital data to an analogue signal; modulate/demodulate the signal; select power, frequency, phase and time interval for transmission; and transmit and receive signals."

NIN002 then goes over some test scenarios such as audio or video, low-power IoT devices and tactile networks.

4.3 NIN003: "Flexilink Network Model"

NIN003 explains that packets are part of flows. Setting up flows can be done by a control plane that is independent of the data plane that will forward those packets based solely on a flow identifier in an approach similar to the one taken by Software Defined Networks (SDN).

Flexilink is a data plane protocol. The control plane is left to another protocol. As a pure data plane where packets are put in virtual circuits identified by a token (similar to MPLS), Flexilink can carry any type of traffic, being IPv4, IPv6, RINA[48] or anything else.

5 NIN vs New IP

New IP is another proposal to replace the TCP/IP protocol stack. Its primary promoter has been Huawei, which has proposed the protocol in the International Telecommunications Union protocol standardization (ITU-T) Study Group 11 and Study Group 13. For more information on New IP, see the ICANN Office of the CTO (OCTO) series document OCTO-017.

Both New IP and NIN share the same starting assumption: they assert without much evidence that TCP/IP is an old protocol, no longer suitable for new applications that require high bandwidth, low latency, or both.

Both New IP and NIN are in their early stages of development. No formal, complete specifications are publicly available.

Both New IP and NIN are addressing the QoS issues by moving the intelligence away from the end-points into the network. However, neither NIN nor New IP specifies a control mechanism to manage competing QoS needs.

New IP and NIN, differ on a major architecture decision. New IP defines a new IP header that includes mechanisms to enable features like the QoS contract, enforced by intermediary routers. This model is reminiscent of "active networks"[49] in which the intermediary elements execute code included within packets. NIN takes the route of separating the control plane and the data plane to establish virtual circuits. This separation allows for the removal of IP headers in packets and its replacement by a much smaller label, allowing for better spectrum efficiency on radio links. In that perspective, New IP is sometimes referred to as "Big IP" where NIN is referred to as "Small IP." It is important to remember that, because packet headers are of different structure and different size, neither New IP nor NIN are compatible with IP.

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[48] See https://www.researchgate.net/publication/346210855_Special_Issue_Post-IP_Networks_Advances_on_RINA_and_other_Alternative_Network_Architectures

[49] See "The IEEE P1520 standards initiative for programmable network interfaces," Biswas J, Lazar AA, Huard JF, Lim K, Mahjoub S, Pau LF, Suzuki M, Torstensson S, Wang W, Weinstein S, IEEE Communications Magazine. 1998 Oct;36(10):64-70.

Another difference is that there is a great deal of confusion in New IP about whether it is meant as a general replacement for IP or if it is meant for private use. In particular, the intricacies of inter-domain routing and the support of competing business models of various ISPs is not discussed. NIN, at least in the current terms of reference, appears to be initially focusing on applications in the RAN, between the wireless device and some gateways.

In many ways, NIN cannot be seen simply as a layer 3 protocol (where New IP clearly is). It resembles a combination of MPLS with the addition of a control plane directly usable by an application on an end device.

6 Analysis

6.1 Back to the Future: Replacing IP Headers with Virtual Circuits

The main point one can derive from reading both ETSI GS NGP 012 and ETSI GS NGP 013 is that the authors believe the datagram model is not suitable for wireless networks for two reasons:

- A datagram must include source and destination addresses. This increases the size of the header to the detriment of the payload, hence reducing the efficiency of the radio link.
- QoS has to be treated hop by hop, which is expensive in terms of router cycles needed to process the packet headers.

NIN proposes to replace datagrams by a combination of virtual circuits for the data plane and an unspecified protocol for the control plane, essentially combining relatively recent (circa 2010) SDN concepts with the technology used in pre-Internet telephony networks. This is a non-trivial change, especially considering the immense success of the Internet, which is based entirely upon datagrams.

6.1.1 Header compression

As discussed previously, a standard IPv4 header is 20 bytes and a standard IPv6 header is 40 bytes. This overhead is significant for very small payload, but negligible for large payload filling up the full 1500 byte maximum transmission unit (MTU) of a typical Ethernet link. Techniques such as Robust Header Compression (ROHC)[50] have been implemented to address this issue.

The ETSI NIN web page[51] states that not having to deploy header compression would save on power consumption; however this is debatable. A paper[52] published in the 2017 IEEE International Conference on Communications Workshops[53] compares Robust Header Compression version 2 (RoHCv2) on Wifi and LTE and concludes: “We find that the adoption

[50] See https://tools.ietf.org/html/rfc4995
[51] See https://www.etsi.org/technologies/non-ip-networking
[52] See https://ieeexplore.ieee.org/document/7962693
[53] See https://ieeexplore.ieee.org/xpl/conhome/7955917/proceeding

of header compression on modern mobile devices will generally not result in increased power consumption based on the extra complexity added by the execution of the algorithms. We also show that the usage of RoHCv2 can potentially even decrease the battery drain on average by about 0.05 W when payloads are small."

It is clearly stated in NIN001 that the desire to avoid using Robust Header Compression (ROHC) stems from the fact that some operators are claiming vendors are charging too much for this feature. A business dispute between vendors and operators about the licensing scheme of the ROHC feature on active equipment at the edge of cellular networks hardly seems to be a reasonable justification for a complete overhaul of the Internet architecture. A large amount of new software would have to be developed, debugged and deployed. This represents significant costs that would have to be borne by the larger community.

6.1.2 Control Plane Overhead

The simplification which NIN offers on the data plane has to be balanced with the complexity introduced by the control plane. When contemplating a control or data plane separation, one needs to take into account the overhead of the control plane, not just the overhead of the data plane. In the NIN or Flexilink model, all packets are grouped in flows; thus, any control plane that the NIN ISG would define would need to instantiate every flow at their onset. The overhead is not big for long-lived flows, but can be huge for short-lived flows. An example of a worst case scenario would be a recursive DNS server operating on a Flexilink network. Each DNS transaction is typically a two packet exchange: a query and a response. The number of flows associated with such an application would be equal to the number of DNS requests.[54]

This variable overhead makes the actual cost-benefit analysis of an architecture like Flexilink very dependent on the type of traffic it is carrying. The characteristics of traffic that may hold today may or may not be true tomorrow if a new application comes along with a different traffic pattern. The datagram architecture of the Internet has proven over the last five decades to be nimble enough to adapt to almost any new type of traffic, allowing for unprecedented economic growth. There may be concerns that an architecture based on an optimization for a certain type of traffic would not enable the same level of innovation and economic growth.

NIN003 points to ISO/IEC 62379-5-2[55] as a possible control plane for audio and video traffic. NIN003 does not say if this would be a good fit for general traffic. There is then a concern that if NIN were to be deployed over the Internet, there might be multiple control planes operating in parallel. There is a clear risk this could create major operational problems: how could switches and routers reconcile conflicting directives given by different control planes?

6.1.3 Flow State Overhead

[54] ICANN managed root server (IMRS) serves about 150,000 requests per seconds across all its instances, with traffic peaking over 10,000 requests per seconds on some instances. See https://stats.dns.icann.org

[55] See https://webstore.iec.ch/publication/6945 "Common control interface for networked digital audio and video products -- Part 5-2: Transmission over networks -- Signalling"

Another way to look at the question of datagram vs. circuit switching is to look at where the state is kept and who is in charge of updating it. In the datagram model, routers do not need to keep a per-flow state, as all the information necessary to forward a packet is kept in the packet header. In the circuit switching model, the circuit switching device needs to maintain this state. Flow creation or deletion is the main job of the control plane. So the amount of the state to keep is proportional to the number of the flows, and the CPU needed for that is proportional to the churn, or the creation and deletion of flows. The KPIs defined in ETSI GS NGP 012 do not take this into account.

6.1.4 Routing Around Failures

A critical point to analyze in network architecture is the resilience of the system in case of a failure of an intermediary node. Any datagram architecture would automatically route packets around the failed router. How this would be done in the proposed NIN architecture is unspecified in the current public documents. One could imagine that a centralized controller responsible for the instantiation of the flows would have to be notified of the failure and then recalculate all flows accordingly before re-instantiating them. Not only would this controller have to deal with the number of flows (let's say 100 flows per device x 10 million subscribers = 1 billion flows), but it would also need to do this extra work while new flows are getting created. In MPLS networks, a similar recalculation happens in the event of a failure of a switch. The main difference is one of scale: most MPLS networks are configured with less than a million Label Switched Paths (LSP), whereas it can be assumed that NIN switches will need to handle several orders of magnitude more flows if they were to operate as core switches on the global Internet.

6.1.5 Complexity

One major point to take into account when comparing network architectures is complexity. Complexity is known to be one of the major causes of outages. According to RFC3439,[56] complexity is the primary mechanism that impedes efficient scaling.

One of the promises of SDN was to reduce complexity by automating tasks[57]. Not everybody shares this opinion. A number of people are looking at SDN as adding extra complexity. In a book titled "Navigating network complexity,[58] Russ White and Jeff Tansura wrote, "Network professionals have often been told that today's modern control planes would simplify their networks. The opposite has happened: Technologies like SDN and NFV, although immensely valuable, are exacerbating complexity instead of solving it."

Evaluating the complexity added to the 5G RAN by the unspecified control plane of NIN will be critical to fully evaluate the impact of the architecture.

56 See https://tools.ietf.org/html/rfc3439
57 For a perspective on how SDN can simplify networks, see https://www.itproportal.com/features/in-terms-of-complexity-cost-and-pace-sdn-is-a-winner/
58 See https://www.oreilly.com/library/view/navigating-network-complexity/9780133987928/

6.1.6 Quality of Service (QoS)

One key feature of Flexilink is the slicing of link capacity into small chunks of 64 bytes and allocating those chunks to flows according to their QoS requirements. This is reminiscent of technologies like ATM, Fiber Distributed Data Interface (FDDI), and Token Ring that were popular in the 1990s but have been almost entirely displaced by Ethernet in its various forms and speed.

NIN seems to conflate the terms Internet, TCP/IP and IP.

- IP is an extendable datagram protocol with little constraints. It is not an impediment to QoS, which can be implemented below (at the data link layer) or above (transport or application layers), depending on the purpose.
- TCP/IP is a protocol suite, creating basic building blocks layered on top of the IP architecture.
- The Internet is an interconnection of networks built on TCP/IP.

NIN001 claims that users of videoconferencing and voice-over-IP applications experience poor service. This is difficult to reconcile with the use of voice-over-IP for most telephony systems and the vast use of IP-based videoconferencing applications particularly during the COVID-19 pandemic. However, this claim is the basis NIN uses to explain that a form of explicit quality of service management is needed. The same discussion made in the analysis of New IP in OCTO-017[59] applies here. Explicit requests for quality of service (QoS) are based on the notion that bandwidth is an expensive and scarce resource that must be managed. The last twenty five years have shown that this is not necessarily the case. Bandwidth has dramatically increased year after year, both in the last mile or residential access and in data center or core networking. Wireless bandwidth has also increased generation after generation, and 5G now promises bandwidth up to 1Gbps for individual end stations.

Are the benefits of explicit QoS worth the price of the added complexity and associated cost? To date, it does not appear so. The economics of the Internet have shown that cheap wins over quality.

6.2 Flexilink for wireless device to gateway communication

Limiting the scope of deployment of Flexilink to the RAN might make any deployment significantly simpler than attempting to use it as a full replacement of IP on the Internet. It could then be seen as just another layer 2.5, like MPLS or Carrier Ethernet[60], with relatively minor impact on the global Internet architecture.

ETSI GS NGP 013 argues that using Flexilink on the RAN would not be more complicated than using a carrier-grade Network Address Translator (NAT) as it is done today. This suggested deployment model would also be similar to a number of existing gateway or proxy solutions

[59] See https://www.icann.org/en/system/files/files/octo-017-27oct20-en.pdf
[60] See https://www.mef.net/service-standards/underlay/carrier-ethernet/

such as RFC1928 SOCKS,[61] with the difference that the communication to the gateway or proxy would not take place over IP, but over Flexilink.

It should be noted that such a model had been tried in the past. In the late 1990s, NTT-Docomo introduced "i-mode"[62] in Japan as a mobile Internet service. Soon after, the Wireless Application Protocol (WAP[63,64]) was defined to access information over a wireless information network.

WAP had limited deployment, mainly for two reasons:

- More powerful handsets and higher bandwidth made TCP/IP on user devices a reality.
- Not all content was available via WAP. Actually, WAP was seen as creating a walled garden for operators.[65]

I-mode peaked at 49 million users in 2010,66 just after the smartphone era began. In 2019, NTT-Docomo announced it will discontinue i-mode in 2026.67

It remains unclear whether the potential gains in radio efficiency are real once we take into account the signaling overhead of the to-be-specified control plane. It also remains unclear if the efficiency gains will be important enough to justify the introduction in the network of new technology elements that would come with their own problems.

NIN002 hints that the 5G architecture is not a simple layer 2 network upon which one could run any layer 3 protocol. According to NIN002, the "clean slate" approach to achieve the maximum benefits of NIN in 5G appears to actually require a complete do-over of 5G. This might be a very tall order. If NIN is a non-starter in 5G, other radio technologies such as DECT202068 would have to be studied for better suitability. This clearly points to NIN being seen as a local network technology suitable at home or in an industrial environment, not something to be deployed at the scale of the Internet.

6.3 Application identifiers

As seen in Section 3.1, ETSI GS NGP 012 hints at new application identifiers. This is a concept similar to the locator-identifier split in architectures like the Locator/IP Separation Protocol (LISP), RFC6830.[69]

This split is one of the fundamental architecture principles in the Recursive Inter-Networking Architecture (RINA[70]), developed by John Day and goes beyond the idea of DNS identifiers that simply map to an IP address. In the IP model, the usage of well-known ports can ensure

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61 See https://tools.ietf.org/html/rfc1928
62 See https://web.archive.org/web/20130305075214/http://www.nttdocomo.com/services/imode/index.html
63 See https://www.openmobilealliance.org/wp/Affiliates/WAP.html
64 See https://www.eetimes.com/wap-gateways-and-servers-delivering-wireless-content/#
65 See https://www.law.gmu.edu/assets/files/publications/working_papers/1150WalledGardenRivalry.pdf
66 See http://akihabaranews.com/the-end-for-i-mode/
67 See footnote 21
68 See https://www.etsi.org/newsroom/press-releases/1839-2020-10-etsi-launches-dect-2020-new-radio-interface-for-iot
69 See https://tools.ietf.org/html/rfc6830
70 See http://www.cs.bu.edu/techreports/pdf/2008-019-IPC-arch.pdf for the seminal paper on RINA

192.0.0.1:80 or www.example.com:80 always point to a web service. By extension, there can only be one service running on any IP address or the well-known port tuple.[71] This creates major problems when IP addresses are shared by a network address translation (NAT) box. Port 80 could only be redirected to a single host. To work around this issue, the port control protocol (PCP[72]) was developed. It enables an application to negotiate the opening of ports on a NAT box. Similarly, software like peer-to-peer platforms uses trackers, which are rendezvous points where applications register the temporary port mapping that the NAT associated to them.

In the RINA architecture, two similar services running on the same host may have completely different identifiers. This is a missing feature of the TCP/IP protocol suite and it remains to be seen if the NIN ISG will actually develop it.

7 Conclusion

As the first three NIN Group Reports are published, the work of the ETSI NIN ISG is still underway. Still, it is possible to see NIN's overall direction: it proposes a return to virtual circuits organized around the division of link capacity into time slots to transmit 64 byte chunks at a time.

However, Flexilink only defines the data plane. The full impact of the proposal cannot be understood without looking at the as yet unspecified control plane,or control planes if more than one were to be used. Gains on one side in terms of efficiency, security, resiliency, etc., could easily be offset by losses on the other, depending on the nature of the traffic. Also, the resiliency of the network remains an open question. Because the control plane is left unspecified, it is impossible to know what would happen in case of a failure of an intermediary node. Also unclear is the impact of that control plane on the complexity of the operation of the network.

It seems that one of the main drivers for NIN is centered on the alleged cost of the ROHC feature, a feature that enables the reduction of the overhead for the IP header to almost zero. To address this perceived business issue, NIN is proposing a complete overhaul of the entire Internet architecture. However, NIN did not provide a full analysis of the total cost of the deployment of the proposed replacement solution, with expenses that would have to be incurred not only by the operators but also by a large number of third parties in the Internet ecosystem.

NIN ISG targets Flexilink at the RAN. Looking at the RAN as a special network that cannot support TCP/IP is nothing new. It was tried in the early days of the wireless Internet by NTT Docomo i-mode and by WAP. However, gains in handset capacity (smartphones) and increases in wireless bandwidth made TCP/IP the norm on those wireless devices. It is unclear that any perceived limitation of TCP/IP for upcoming wireless applications will require a significant overhaul of the network architecture or whether simply waiting for the next generation of handsets will suffice. That being said, as Flexilink can be seen as a Layer 2.5 protocol like MPLS or Carrier Ethernet, if the deployment model is limited to the RAN, the impact on the global Internet architecture could be minimal.

Similar to New IP, NIN is revisiting some fundamental networking tenets. This is certainly a healthy exercise. However, in both cases, the proposed solutions are gravitating around the

[71] Although a single web server can host multiple web sites
[72] See https://tools.ietf.org/html/rfc6887

return of an architecture of the past, in what seems to be a relitigation of the datagram vs virtual-circuits debates of the last century.

Making sure the architecture of any new proposed networking model is compatible with the Internet architecture is a key factor to preserve end-to-end connectivity and keep the vision of one world, one Internet.